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(57) Claim 1. Solar energy conversion apparatus comprising concentrating means having first and second portions, tracking means for causing the concentrating means to track the sun, and solar energy utilization means moveable with the concentrating means and having first and second faces, the arrangement being such that when the concentrating means is directed at the sun, the first and second portions concentrate solar energy into first and second lines which are on or adjacent to said first and second faces respectively.

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Complete specification for the invention entitled:

"SOLAR TRACKING APPARATUS"

The following statement is a full description of this invention, including the best method of performing it known to us :-

This invention relates to solar energy conversion apparatus.

More particularly the invention is concerned with collection apparatuses which track the sun and concentrate solar energy onto an energy utilization surface. The efficiency of such systems depends on:

(1) the quality of the concentrating means, that is to say, the proportion of energy which is focused at a line or point and the sharpness of the line or point. A sharp line or point enables the collecting surface to be smaller and thus minimize losses from the collecting surface;

(2) the accuracy with which the apparatus tracks the sun;

(3) the efficiency of energy utilization at the collecting surface.

The present invention is chiefly concerned with the last of the above mentioned aspects.

According to the present invention there is provided solar energy conversion apparatus comprising concentrating means having first and second portions,

tracking means for causing the concentrating means to track the sun, and solar energy utilization means moveable with the concentrating means and having first and second faces, the arrangement being such that when the concentrating means is directed at the sun, the first and second portions concentrate solar energy into first and second lines which are on or adjacent to said first and second faces respectively.

The apparatus defined above utilizes a dual focal line trough which has energy utilization faces optimally oriented relative to the mean direction of radiation reflected from the trough. The advantages are where photovoltaic cells are used for generation of electric power or control signals since such cells normally have a flat surface and the flat surfaces of the cells can be located transverse to the mean direction of radiation incident thereon and so increase their efficiency.

The invention will now be further described with reference to the accompanying drawings, in which:

Figure 1 is a perspective view showing a solar energy conversion apparatus embodying the invention mounted on the roof of a house,

Figures 2 and 2A are perspective views of part of the parabolic reflector and its support structure respectively,

Figure 3 is a cross sectional detail showing the manner of construction of the parabolic reflector,

Figure 4 is a side view of the detail illustrated in Figure 3,

Figure 5 is a cross sectional view through the central portion of the reflective trough,

Figure 6 is a detailed plan view at the central portion of the trough,

Figure 7 is an end view of the apparatus illustrated in Figure 1,

Figure 8 is a side elevation of one form of the invention,

Figure 9 is a detail of the upper bearing for the trough,

Figure 10 is a detail of the lower bearing for the trough,

Figures 11, 12 and 13 are diagrams useful in understanding the principles of operation of the invention,

Figure 14 is a cross sectional view taken along the line 14-14 marked on Figure 8,

Figures 15, 16 and 17 correspond generally to Figure 14 and illustrate the mode of operation of the apparatus of the invention,

Figure 18 is a cross sectional view taken along the line 18-18 marked on Figure 8,

Figure 19 is a cross sectional view taken along the line 19-19 marked on Figure 18,

Figure 20 is a cross sectional view taken along the line 20-20 marked on Figure 18,

Figure 21 is a cross sectional view taken along the line 21-21 marked on Figure 20,

Figure 22 is a cross sectional view taken along the line 22-22 marked on Figure 8,

Figure 23 is a cross sectional view of the heat ~~head~~ collecting tube taken along the line 23-23 marked on Figure 8,

Figure 24 illustrates a modified form of heat transfer tube,

Figures 25 and 26 illustrate a preferred form of support structure for the trough, and

Figure 27 illustrates schematically one arrangement for preventing over-heating of the apparatus.

The solar energy conversion apparatus of the invention comprises a reflective trough 2 having parabolic portions 2a and 2b having focal planes 7a and 7b and connected by a flat 9 at the base of the trough. As seen in Figures 7 and 1 the trough 2 is mounted for rotation about an axis 4 which is midway between focal lines 3a and 3b of the parabolic portions 2a and 2b of the trough. A heat transfer tube 6 for passage of a heat transfer fluid extends along the axis 4 but is moveable with the trough and has dimensions such that the focal lines 3a and 3b impinge on or near its surface. The ~~preferred~~ cross sectional configuration of the tube 6 is shown in Figure 23, the tube having flats 31a and 31b facing the portions 2a and 2b of the trough. The upper part of the tube is preferably insulated by insulation 125 located within a channel 127, as seen in Figure 23. The trough 2 is carried by a trough support structure generally indicated by 8, the structure 8 being mounted for rotation in a framework 10 as shown in Figure 2A. The trough support structure 8 and framework 10 are mounted within a housing 12 (which has only been illustrated in Figures 1 and 7 for clarity of illustration). The upper part of the housing 12 is made from glass or acrylic material so as to be substantially transparent to solar energy.

Referring now more particularly to Figure 2A, the framework 10 comprises a pair of triangular end supports 14 the lower parts of which are interconnected by two elongate lower beams 16, the apices of the triangular

supports 14 carrying upper and lower bearings 18 and 19 for mounting the trough support structure 8. The trough support structure 8 comprises an elongate beam 20 from which a number of transverse arms 22 project for providing support for the side edges of the trough 2. The end of the beam 20 is connected to upright transverse beams 34 and 36 each extending above and below the beam 20. In addition, a short transverse beam 38 extends downwardly from one end of the beam 20. The framework 8 has a pair of tubular spigots 40 and 42 which project outwardly from the end transverse beams 38 and 34 and are received within the bearings 18 and 19 so that the support structure 8 is rotatably mounted within the framework 10 about the axis 4. The framework 8 also includes a tension member 33 extending between the free ends of the beams 34 and 36.

The support structure 8 and trough 2 are arranged to be balanced (or nearly so) so that their combined centre of gravity is co-incident with the axis 4 so as to minimize the forces required to effect rotation of the trough. In practice the support structure could be provided with adjustable weights to achieve the correct balancing. Additionally the arrangement is preferably such that the trough is slightly biased away from the centre position as illustrated in Figure 7.

The novel technique for forming the parabolic trough 2 is illustrated in Figures 2 to 6. In this arrangement, there is a plurality of ribs 102 each of which is formed with a

concave edge 104 which is parabolic in shape. The reflective trough 2 is formed by resiliently depressing a flat sheet of reflective material such as aluminium into contact with the parabolic edges 104 of the ribs 102. In this manner an accurately formed parabolic trough can be manufactured at very low cost. In the illustrated arrangement, the trough is formed in two portions 2a and 2b but the principles are equally applicable to a single parabolic trough. The upper ends of the ribs 102 are connected to the free ends of the arms 22 and the free ends of the arms 22 are additionally braced by bracing members 24. The centres of the ribs 102 are connected together by means of a longitudinally extending channel 35. The interconnection of the channel 35 and the ribs 102 is preferably by means of downwardly projecting tabs 37 punched from the web of the channel and affixed to the ribs 102. In the illustrated arrangement, the trough portions 2a and 2b are formed by flat sheets of aluminium which are formed with L-shaped flanges 39 and 41 along their inner and outer longitudinal edges respectively. The flanges 39 and 41 strengthen the side edges of the sheets and prevent unwanted distortions of the sheets in the unsupported regions between the ribs 102. Additionally, the flanges 39 and 41 are used in the connection of the sheets to the ribs.

As can be seen from Figures 2 and 5, the inner flanges 39 engage the upstanding legs of the central channel 35 and so locate the inner edges of the aluminium sheets. The flanges 39 are retained in position by means of clips 43 which extend from the web of the channel 35 and engage the top faces of the L-shaped flanges 39. The interconnection of the clips 43

with the web of the channel 35 is preferably by means of tabs 45 which are pressed from the web of the channel 35. As shown in Figure 5, the L-shaped flange 39 is initially at right angles to the flat sheet of aluminium as indicated in broken lines in Figure 5 but in its operative position it is deflected inwardly somewhat by the channel 35 and this assists in maintaining snug engagement of the sheet with the parabolic edge 104 of the rib to improve the fidelity of the resultant parabolic surface.

The outer L-shaped flanges 41 are used to interconnect the sheets to the upper ends of the ribs 102, as best seen in Figures 3 and 4. The clips 47 are provided with oppositely directed end portions 49 and 51 which pass through appropriately located recesses so as to hold the sheet in position firmly against the parabolic edge 104 of the ribs.

In addition to the clips 43 and 47, it is preferred that the inner flanges 39 are fixed at the centre of each sheet to the channel 35 so as to permit thermal expansion of the sheets in the longitudinal direction. Any thermal expansion of the sheets in the lateral direction is accommodated by means of flexure of the springs 47. The upper flange 41 is inclined somewhat outwardly of its final position as indicated in broken lines in Figure 3 and this assists in attaining the correct parabolic configuration of the surface.

The details of a preferred form of upper bearing 18 are illustrated in Figure 9. In this arrangement, the tubular spigot 40 has mounted thereon the inner race 53 of a ball bearing, the outer race 55 of which is connected to the triangular support 14. The inner race 53 is provided with an annular grove for receipt of spherical ball 57 in the usual manner. The outer race 55 is however not provided with a groove so that only the annular inner surface of the race makes contact with the balls 57. It has been found that a bearing produced in this manner has very low friction. A similar bearing could be made without any grooves to further reduce friction and reduce the likelihood of jamming where there are misalignments. Of course, such bearings cannot support any axial thrust which is necessary when the apparatus is mounted on an angle as is illustrated in Figure 1. The thrust exerted by the weight of the trough and its support structure 8 is arranged to be borne by a thin wire 59 which extends fully through the heat transfer tube 6 and is connected to the lower end of the support structure 8, in the manner illustrated in Figure 10. The upper end of the wire 59 passes from the end of the tube 6 and is coupled to the end support 14 in the manner illustrated in Figure 9. The end of the tube 6 is connected to a length of rubber tube 61 which in turn is connected to a tube 63 of low friction plastics material, the end of the tube 63 being received within a stationary fluid coupling 65, the coupling being formed with a recess in which a seal 67 is located. It has been found that the tube 61 and 63 together with the seal 67 form an effective rotatable coupling for the heat transfer tube 6. The end of the wire 59 passes through a boss 69 formed in the coupling

65 and is formed with a loop 71 located in a recess 73. The recess is closed by means of a threaded cap 75 which is threaded onto a threaded portion of the boss 69. A seal 77 is interposed between the end of the boss and the inside of the cap 75. The fluid coupling 65 is housed within and supported by a generally cup shaped support member 79 which is fixedly connected to the triangular support 14. An adjusting nut 81 is provided on the threaded portion of the boss 69 and it is used to adjust the axial position of the boss 69 and hence of the wire 59 with respect to the stationary cup 79. A washer 83 is interposed between the nut 81 and the end of the cup support 79.

The lower bearing 19 is illustrated in Figure 10 and it can be seen that the tubular spigot 42 extends from the beam 34 into a recess provided in the triangular support 14. The free end of the spigot 42 is provided with a grooved inne ball race 85 for receipt of balls 87, the balls co-operating with an annular outer race 89 which is connected to the support 14. The end of the tube 6 is connected to a cone shaped support 91 which carries a spider 93 having a hub 95 through which the end of the wire 59 extends. The wire 59 is formed with a loop 97 for forming a connection with the outer face of the hub 95. In this manner substantially all of the axial forces at the bearing 19 are borne by the wire 59. The rotations of the trough cause torsional twisting of the wire 59 but the tortional resistance of the wire is exceedingly small over its length. The fluid coupling is completed by

means of a funnel shaped member 99 which is connected to the cone shaped support 91, a rubber tube 101 being connected to the tubular portion of the support 99. The other end of the tube 101 is coupled to a tube 103 of low friction material which in turn is inserted into the end of a stationary fluid coupling 105 which has a seal 107 located in a recess therein. The fluid coupling 105 is supported by a cup shaped support 109 projecting outwardly from the triangular support 14.

In the illustrated arrangement, the heat transfer tube 6 is rotatable with the trough and support structure 8 but it is to be understood that the tube 6 could be stationary since it is located along the axis 4 of rotation.

In order for the sun's rays to be focussed by the trough 2 onto the heat transfer tube 6, it is necessary that the trough be made to track the sun. In the arrangement described herein the tracking is in azimuth only i.e. the trough follows the movement of the sun from its rise in the east to setting in the west each day. The principles upon which the invention relies to effect tracking movements can best be appreciated with reference to Figures 11 to 13.

Figure 11 shows a cross section through the trough 2 (which need not be formed with a flat at its centre) and having a focal line 3. A well known property of parabolas is that all rays 5 impinging on the trough and parallel to the principle plane 7 are reflected through the focal line 3. When the trough is used for collecting solar energy, heat absorbing means is

located along the focal line and will thereby receive substantially all of the solar energy reflected from the trough 2. Figure 11 also illustrates that the profile of the parabola can be altered to the form as indicated by the parabolas 2A and 2B shown in broken and chain lines respectively without losing any energy gathering performance and this provides some flexibility in the location of the trough relative to the focal line 3.

Figure 12 illustrates the trough divided into two portions 2a and 2b which are spaced apart by a distance D. Each portion produces its own focal line 3a and 3b respectively, the focal line 3a and 3b being separated by the distance D. A single heat absorbing member can be located so as to have energy focussed thereon by the two portions 2a and 2b, as for instance with the flats 31a and 31b of the tube 6 as is illustrated in Figure 23, the flats being transverse to the mean direction of incident radiation from the respective portions 2a and 2b.

Referring back to Figure 11, the single parabola can be considered as two separate parabolic portions which lie upon the same parabolic surface and thus focii of the two portions are co-incident at the true focus 3 of the trough.

Figure 12 illustrates the effect of light impinging upon the trough portions at angles A° relative to the principle planes 7a and 7b of the trough portions. It will be noted that the sharp focal lines become somewhat defocussed and such defocussed lines will be referred to hereinafter as "quasi-focal lines". Further, for deviation of A° to the left as seen in Figure 12, the quasi-focal line 3a migrates somewhat downwardly and inwardly relative to the true position of the

focal line 3a and the quasi-focal line 3b moves somewhat upwardly and outwardly. Correspondingly, when the deviation angle A^{o} is to the right the quasi-focal line 3a moves upwardly and outwardly and the quasi-focal line 3b moves downwardly and inwardly. The two portions 2a and 2b could of course be formed as a single trough which has a flat 9 interconnecting the two portions 2a and 2b.

Figure 13 illustrates a more complicated trough made up from a plurality of integral parabolic segments 2e to 2j but again forming spaced focal lines 3a and 3b.

In the present invention, the property of the migration of the quasi-focal lines is used to effect tracking movements by arranging for the quasi-focal lines to migrate onto heat sensitive elements to thus selectively heat one of the heat sensitive elements more than the other depending upon the direction of misorientation.

The arrangement for effecting tracking movements of the trough will now be described with particular reference to Figure 8 and Figures 14 to 22. The arrangement includes two heat expansible metallic rods 44 and 46 having matt black surfaces for good energy absorption the rods being generally parallel and one end of each is connected to the transverse beam 34 by means of a spring 48. The rods are preferably connected to a block (not shown) to which the spring 48 is connected and guide means 111 is provided to bear against one or other of the rods 44 or 46 to restrain any rocking or sideways movement of the rods 44 and 46. The rods 44 and 46 lie in planes which are

parallel to and closely spaced to the focal planes 7a and 7b of the trough portions 2a and 2b respectively. As seen in Figure 8, the rods 44 and 46 extend generally diagonally at an angle of about 15° with respect to the focal lines 3a and 3b and their upper portions project from the trough and extend through an opening 50 formed into the transverse beam 36. The rods 44 and 46 extend through openings in the channel 35 and project beneath the trough 2. The rods extend diagonally so as to receive reflected radiation even when the trough is grossly misaligned with the sun in which case the quasi-focal lines lie close to the surface of the trough. The pair of diagonal rods 44, 46 could be replaced by arrays of parallel strips to achieve the same effect. As best seen in figure 19, the ends of the rods 44 and 46 are formed with openings 52, the forward portions of which are formed with pointed edges 54 which are located within respective V-notches 56 and 58 formed into a shaft 60 as best seen in Figure 21. The shaft 60 extends between a pair of sides of body 62 having a central rectangular opening 64. The upper and lower ends of the body 62 are formed with V-notches 66 which receive knife edges 68 projecting outwardly from a mounting plate 70 which is connected to the upright transverse beam 36. The body 62 is held in engagement with the knife edges 68 by means of the tensile forces from the tension spring 48 transmitted through the rods 44 and 46. Thus, the body 62 is rotatable about an axis 72 which passes through the tips of the knife edges 68 and is perpendicular to the axis 4 of the trough or alternatively to the direction of the rods 44 and 46.

The body 62 has extending therefrom an arm 74 which branches into two arms 78 which serve as mounting points for a wire 80 which convolutes about a drum 82 which is fixedly connected to and extends inwardly from the support 14, as seen in Figure 18. The wire 80 passes about a pair of rollers 84 which are mounted upon arms 86 projecting outwardly from the beam 38, the rollers 84 serving to maintain the lead-in and lead-out portions of the wire 80 about the drum 82 as two tangents to the drum 82.

In operation, differential thermal expansion of the rods 44 and 46 due to misalignments of the trough with the sun cause rotation of the body 62 about the axis 72 thus causing rotation of the arm 74. This causes consequential movement of the wire 80 relative to the drum 82 and such rotation of the arm 74 causes part of the wire 80 to wind onto the drum and a corresponding part to unwind from the drum accompanied by a rotation of the trough support structure 8 about the axis 4 of the trough.

In an alternative arrangement, the wire 80 could be replaced by a curved rack gear which meshes with a tooth gear which would replace the drum 82. Such a geared arrangement would function in a similar manner to the wire and drum arrangement as illustrated. In a further modified arrangement, the trough support structure 8 and components carried thereby are arranged to be balanced so that the centre of gravity of the rotatable assembly is co-incident (or nearly so)

with the axis 4 of the trough. In such an arrangement, the body 62 is connected to symmetrically disposed weights which, when the body 62 is rotated from its central position, are shifted and so alter the overall centre of gravity of the rotatable assembly. The unbalanced assembly will then rotate in the appropriate direction so as to realign the focal plane of the trough with the sun. In one form of such apparatus the weights could be located in positions which correspond generally to the positions of the downwardly extending arms 78, but inwardly over the trough 2. The differential expansion of the rods 44 and 46 could, of course, be utilized to control known means for causing rotation of the trough.

The rods 44 and 46 are located generally beneath the beam 20 and when the trough is directed at the sun, the beam 20 shades the rods from direct sunlight. Except at the region where the rods 44 and 46 cross over the focal lines 3a and 3b of the trough, the rods will not receive any solar energy reflected from the trough when the trough is directed at the sun. In the region of cross over of the rods with the focal lines, the rods will receive generally equal amounts of solar energy and any consequential thermal expansion of the rods will be the same in each rod and will not cause rotation of the body 62. Any slackness in the rods will be taken up by the spring 48 which also serves to compensate for the effects of changes in ambient temperature.

When the focal planes 7a and 7b of the trough are not directed at the sun the focal lines 3a and 3b become quasi-focus lines one of which moves laterally and downwardly relative to the true focal line and the other of which moves ———————————

in generally the opposite direction that is upwardly and laterally in the opposite direction to the other quasi-focal line as illustrated diagrammatically in Figure 12. As seen in Figure 12, where there is a deviation of A^{O} between the sun's rays 90 and the focal plane 7b, the reflected rays 91 will form a quasi-focal line 3b which impinges upon the rod 46 and so causes expansion thereof. The other quasi-focal line 3a will be above the rod 44 except for the portion which is above the level of the axis. However, this area of the rod 44 (and of the rod 46) is shielded from reflected radiation by means of a U-shaped reflective tunnel 92 which is mounted over the rods 44 and 46. Expansion of the rod 46 will cause the body 62 to pivot in an anti-clockwise direction as seen in Figure 18 which will thus cause the trough support structure 8 to rotate clockwise (as seen in Figure 15) by virtue of the interconnection of the wire and the drum 80 and 82. The clockwise rotation of the trough support structure will continue to a point where the focal planes 7a and 7b are parallel with the incident radiation 90 whereupon both rods 44 and 46 both receive radiation and rotation will cease with the focal plane being substantially correctly aligned with the sun, as shown in Figure 16. To remain stable it is necessary for the rod 46 to receive more radiation than the rod 44 so the trough will be slightly misaligned in an anti-clockwise direction, except when the plane of the trough is vertical in which case the rods receive the same amount of radiation and are at the same temperature. Generally speaking, for stability, the amount of temperature differential of the rods increases linearly from the vertical position with the angular orientation of the trough. The requirement for increasing temperature differential with

increasing orientation from the vertical can be off-set by weights which tend to rotate the trough away from its vertical position. A similar effect takes place when the sun's rays 94 are offset by an angle A^{o} as seen in Figure 17. This time the inward quasi-focal line 3a is focussed upon the rod 44 and the rod 46 does not receive any reflected radiation. Heating of the rod 44 will cause rotation of the body 62 in a clockwise sense as seen in Figure 18 and this will produce rotation of the trough support structure 8 in an anti-clockwise sense as seen in Figure 17 to correctly align the focal planes 7a and 7b with the sun's rays.

A reflective shield 113 is located between the rods 44 and 46 so as to prevent unwanted radiation striking the rods from the opposite side of the trough which would tend to counter the differential heating of the rods. The shield is carried by means of clips 115 which, in turn are carried by the rods 44 and 46 as illustrated in Figure 22.

It will thus be appreciated that the tracking arrangement described herein can effect tracking movements of the trough without the need for any external energy input and relies solely on received solar radiation.

In the illustrated arrangement, the rods 44 and 46 includes slots 96 and 98 located generally at the region of intersection of the rods with the focal lines 3a and 3b of the trough. The purpose of the slots is to effectively double the amount of radiation available for fine tuning of the trough when at or near the point of correct alignment with the sun. As illustrated in Figure 16 where the sun's rays 100 are parallel to the focal planes 7a and 7b of the trough the

reflected rays will just impinge upon the lower portions of the rods 44 and 46 adjacent to their respective slots 96 and 98. When however the sun's rays are separated by an angle A as shown in Figure 15 the quasi-focal line 3a will also impinge upon the rod 46, rays from the parabolic portion 2a passing through the slot 96 and impinging upon the rod 46. The quasi-focal line 3b will still impinge upon the rod 46 as before and thus the provision of the slots greatly increases the amount of heat applied to the rod 46 for effecting the necessary correcting movement. Figure 17 illustrates a similar effect with a deviation angle of $-A^{o}$. The target tube 6 is flattened and bent downwardly adjacent to the slots so as not to obstruct light passing through the slot in one rod to the other rod, as seen in Figure 8. The housing 92 includes a reflective baffle 117 which assists in reflecting light onto one rod which has passed through the slot in the other rod. Unwanted reflected radiation is shielded by reflective elements 119 covering the upper surfaces of the rods at the slots, as seen in Figure 14.

The preferred shape for the slots is apparent from Figures 8 and 14. The slot is parallel to the axis 4 and is formed by removing portions of the material of the rods, then bending the rods outwardly to form laterally projecting portions 44a and 46a above their respective slots.

The trough is balanced such that in the absence of any direct solar radiation the trough will return to a position in which the focal planes are vertical. Thus in the night or when the sun is behind thick cloud the trough 2 will be at the noon position which may be very substantially misaligned with

the actual direction of the sun. For instance, in the morning when the sun rises the deviation is approximately 90° and no rays can strike the reflective part of the trough to initiate tracking. This potential problem could be avoided by having the top edges of the trough below the level of the focal lines 3a and 3b so that the sun's rays can directly impinge upon one of the rods 44 or 46 in the region above the top edges of the trough and below the focal lines 3a and 3b. Once one of the rods 44 or 46 has been heated it will cause at least some rotation of the trough and then the reflective interior of the trough will become effective. As the trough rotates to correct alignment the quasi-focal 3b or 3a will gradually move up the rod 46 or 44 (depending upon the direction of the misorientation) until the slots 98 or 96 are reached and thereafter correct tracking will continue as long as direct solar radiation is received. A similar effect is achieved in the illustrated arrangement by the lower portions of the rods 44 and 46 which extend below the trough 2.

In a prototype apparatus it has been found that a torque of approximately 650 cm-gms or a temperature differential of about 3.5° C between the rods 44 and 46 is required to rotate the trough from its rest position through 90° so that the focal planes 7a and 7b are directed to the west or east. When the sun is at or near these extreme positions it is at its weakest but maximum torque is required at these times. The potential problem can be offset by loading the trough by means of eccentric weights or springs which assist the trough in moving to its extreme positions this can be done by putting a weight

on the beam 20 which at the due east or due west position has a downward torque of just less than 650 cm-gms, the torque required to effect rotation through 90°. With this modification the apparatus has little difficulty in tracking the sun even when the received rays are very weak since the temperature differential required between the rods 44 and 46 is substantially reduced.

The heat transfer tube may have mounted thereon two rows of photo electric conversion elements ~~(not shown)~~ which are arranged to have solar energy focussed upon them from the trough 2 and excessive overheating of the photoelectric elements is avoided by arranging for them to be in intimate thermal contact with the heat transfer tube 6 which thus serves as a cooling agent for the elements. Such an arrangement has the advantage that it produces a certain proportion of electrical energy and the heat used to cool the elements is imparted to the heat transfer fluid in the tube 6 and thus is utilised in the normal manner.

In a modified form of the invention the trough could be made up from a row of dome portions arranged to more intensely heat some areas of the tube 6. In such an arrangement it would be desirable to track in elevation as well as azimuth but the former could be effected by clockwork or manually since the daily adjustment needed is small.

The trough 2 may have mounted beneath it one or a number of black plate solar absorbers which will receive various amounts of solar energy depending upon the orientation of

the trough 2 with respect to the housing. Further, the absorbers will also receive diffuse solar radiation which is essentially not utilised by the trough 2. In order to improve the performance of the absorbers a pair of reflective plates may be provided so as to reflect light onto the absorbers. The reflectors can be fixed in location and in such a case it is preferred that they be set at about 45° with respect to the focal plane 7 of the trough 2. However, it is preferred that the reflectors be coupled to the trough 2 so as to rotate therewith to thereby reflect more light towards the absorbers. Maximum performance can be obtained by arranging for the rate of rotation of the reflectors to be approximately half the rate of rotation of the trough 2. This can of course be simply effected by having a drive sprocket or pulley mounted upon the shaft carrying the trough 2 coupled by means of chains or drive bands to sprockets or pulleys of different diameters to that provided on the trough shaft. Such a coupling will provide rotation in the required sense and at the required rate of rotation relative to that of the trough 2.

The arrangement described immediately above can be used most advantageously in a hot water system. The heat transfer tube 6 is arranged to draw from and to return very hot water to the upper part of a hot water storage tank, whereas the absorbers are arranged to draw from and to return relatively warm water to the lower part of the same tank. Hot water to be used is drawn from the top of the tank, where the water is hottest and cold water is replaced at the bottom of the tank.

Figure 24 illustrates a modified form of heat transfer tube 6. In this arrangement, there is provided an inner tube 150 which is formed with the flats 31a and 31b as is illustrated in Figure 3. The tube 150 is made from non-electrically conductive material such as glass or alternatively comprises a metal covered with insulating material such as vitreous enamel. Mounted on the flats 31a and 31b are thermo-electric elements 151 and 152, the elements 151 and 152 and the tube 150 being located within an outer tube 153 of transparent material such as glass, any gaps between the tubes 150 and 153 being filled by transparent plastics material. The arrangement is such that the thermo-electric elements 151 and 152 are electrically insulated from the inner tube 150 and the outer layer 153 serves to protect the surfaces of the elements. Even though the sun's rays are concentrated upon the thermo-electric elements 151 and 152 they are prevented from over heating by the heat transfer fluid passing through the inner tube 150.

Figure 27 illustrates schematically one arrangement for causing the apparatus to stop tracking to prevent over-heating of the apparatus in the event that the flow of fluid through the tube 6 is obstructed. In this arrangement, the general principle is to deactivate the tracking means when an excessive temperature is sensed on the tube 6. In the illustrated arrangement, a bi-metallic element 154 is mounted on the tube 6 and is arranged to lie just beneath the arm 74 of the drive mechanism. The arm 74 is provided with a lockable hinge 156 which is arranged to be tripped by the bi-metallic element 154 on overheating of the tube 6 so as to effectively

decouple the drive arrangement. Once the hinge 156 of the arm 174 has been tripped, it will cause the arm 74 to go slack and the trough will simply rotate to its neutral position and will no longer follow the sun. A similar effect could be achieved by causing the drum 40 to become rotatable at higher temperatures and this could be achieved by mounting the drum 80 by means of fuseable material such as solder. The arrangement illustrated in Figures 1 to 26 inherently achieve the same result by excessive thermal expansion of the wire 59 which would cause the trough support 8 to rest against fixed components and so prevent further rotation.

Figures 25 and 26 illustrate a modified mechanical arrangement which effectively eliminates the need for the transverse beam 34 which in practise needs to be quite substantial so as to effectively resist the tensile forces in the rods 44 and 46. In the modified arrangement, a tube 158 of rectangular cross-section is pivotally mounted over the bar 20 by means of a pin 160, washers 162 being located between the inner faces of the tube 158 and the bar 20, as illustrated in Figure 26. Arms 164 and 165 project outwardly from the ends of the tube 158 and the spring 48 which serves as a mounting for the rods 44 and 46 is connected to the free end of the lower arm 164. The relatively large tensile forces which are generated in the rods 44 and 46 are countered by tension rods 166, 167, 168 which act between the arm 164 and tube 158, and between the arm 165 and tube 158, and between the arm 165 and the transverse beam 136 respectively. Any changes in the effective length of the

pair of rods 44 and 46 is accommodated by means of pivoting of the tube 158 about the pin 160. It is to be noted that with the configuration as illustrated the only members which are under compression are the arms 164 and 165 and these are not subjected to any substantial bending movements and thus can be of comparatively light construction in view of the sizes of the forces generated in the rods 44 and 46. It is preferred that the pin 160 be located at the combined centre of gravity of the tube 158, arms 164 and 165, and tension rods 166 and 167 so that rotations of the tube 158 does not affect the overall balance of the system. The balance is also not disturbed significantly if perpendicular lines from the ends of the rod 168 and rods 44, 46 pass through the pin 160.

The end supports 14 could be replaced by frame members which act as supports for glass panels of the housing 12. The upper frame member is preferably of pyramid construction and has the end of the wire 59 affixed to its apex. This construction has been found to be particularly light and strong. The load on the apex of the pyramid frame by the wire 59 is directed inwardly and tends to rotate the pyramid frame inwardly from the base. Such inward rotation can be restrained by one of a pair of light tension members acting between the base of the pyramid frame and the outer side of the other frame member.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Solar energy conversion apparatus comprising concentrating means having first and second portions, tracking means for causing the concentrating means to track the sun, and solar energy utilization means moveable with the concentrating means and having first and second faces, the arrangement being such that when the concentrating means is directed at the sun, the first and second portions concentrate solar energy into first and second lines which are on or adjacent to said first and second faces respectively.

2. Apparatus as claimed in claim 1 wherein said faces are respectively transverse to the mean direction of incident solar radiation forming said first and second lines.

3. Apparatus as claimed in claim 2 wherein said faces include photovoltaic elements.

4. Apparatus as claimed in claim 3 wherein said photovoltaic elements are mounted on a heat transfer conduit which receives heat energy from said elements and/or solar radiation concentrated thereon by said concentrating means.

5. Apparatus as claimed in any preceding claim, wherein the tracking means including first and second elongate metallic members which are disposed relative to the concentrating means to be differentially heated by solar energy when the concentrating means is misaligned with the sun, the differential heating of said

metallic members producing differential thermal linear expansions thereof and drive means for producing tracking movements of said concentrating means in response to said differential linear expansions of said metallic members.

6. Apparatus as claimed in claim 5 wherein radiation shielding means is located between said first and second members.

7. Apparatus as claimed in claim 5 or 6 wherein one end of each of said members is resiliently connected to said support structure.

8. Apparatus as claimed in any one of claims 5 to 7 as appended directly or indirectly to claim 4 wherein the apparatus includes a framework, a support structure rotatably mounted by hollow bearing members in said framework for rotation about an axis, said conduit located along said axis and passing through said hollow members.

9. Apparatus as claimed in claim 8 wherein one end of each of said members is connected to a rotatable body which is rotated in accordance with the differential expansions of said members, the drive means producing tracking movements of said concentrating means in response to rotation of said body.

10. Apparatus as claimed in any preceding claim wherein said concentrating means comprises a trough having a plurality of ribs spaced from one another in the direction of extent of the trough and extending

transversely to said direction, each rib having first and second concave parabolic edges and, first and second sheet portions which are resiliently deformed against at least pairs of said first and second edges respectively, whereby said sheet portions assume concave parabolic configurations.

11. Apparatus as claimed in claim 10 wherein the said sheet portions have upturned flanges at edges thereof which define longitudinal edges of the trough, said trough including means for resiliently biasing said flanges in a direction towards the ribs and inwardly of the trough.

12. Apparatus as claimed in claim 11 wherein the said resilient means comprises spring clips.

13. Apparatus as claimed in claim 10, 11 or 12 wherein said ribs each have a central portion between its first and second parabolic edges, said central region having a width which is generally the same as the spacing between said first and second lines.

Dated this 2nd day of December, 1981

VULCAN AUSTRALIA LIMITED
by its Patent Attorneys
DAVIES & COLLISON.

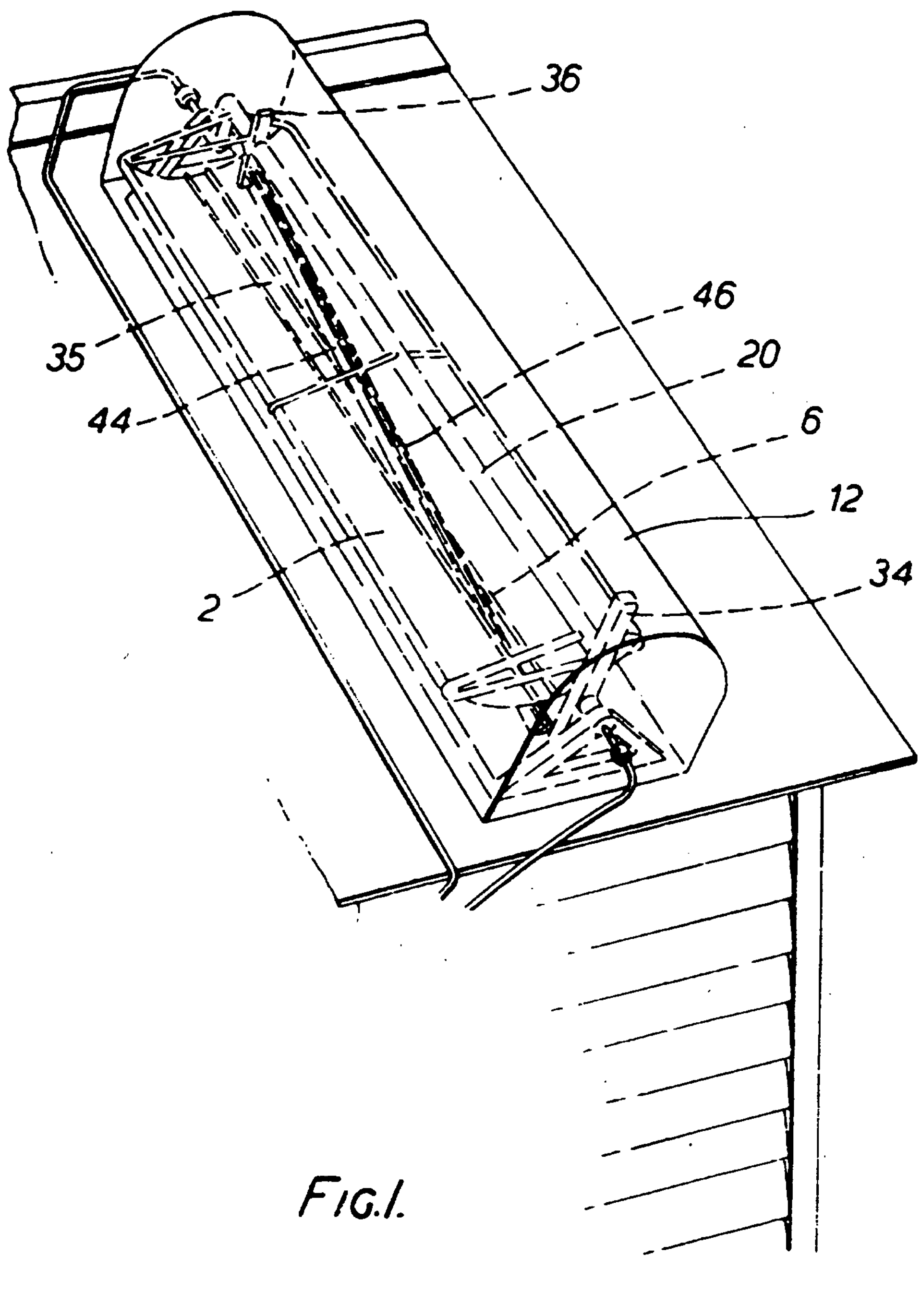

FIG.1.

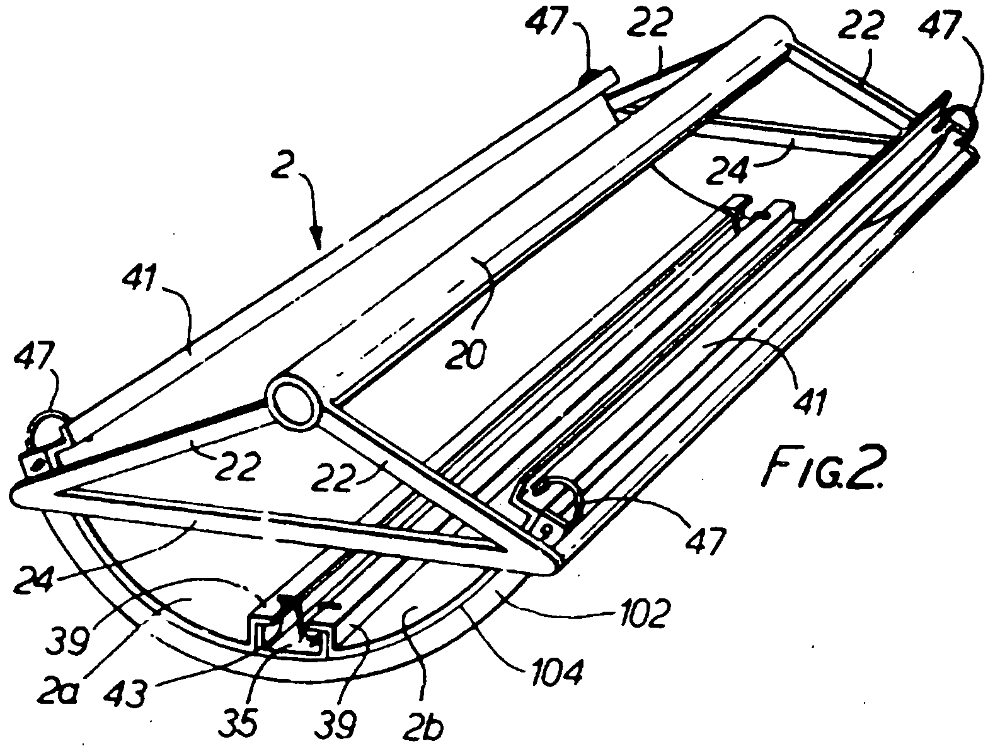
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FIG.2.

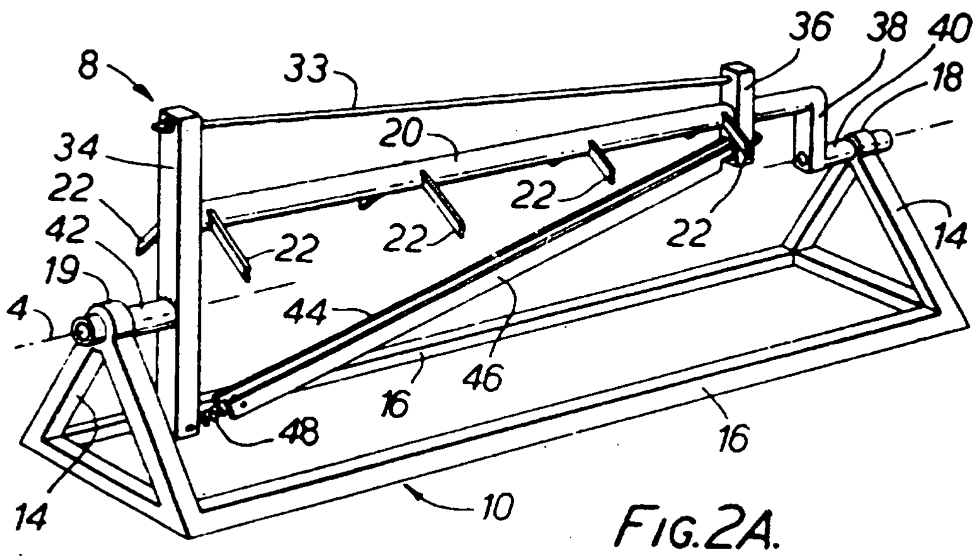
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FIG.2A.

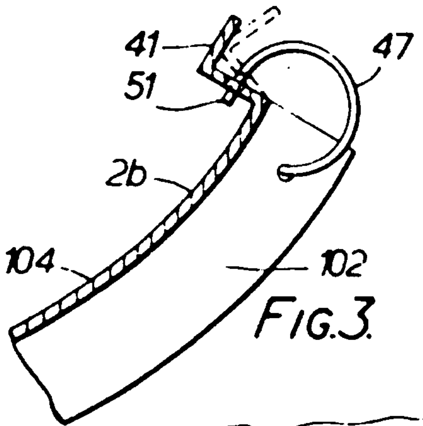

FIG.3.

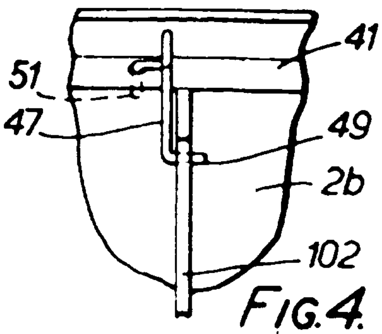

FIG.4.

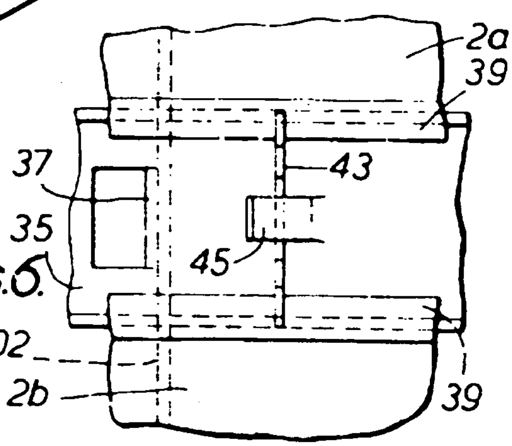

FIG.6.

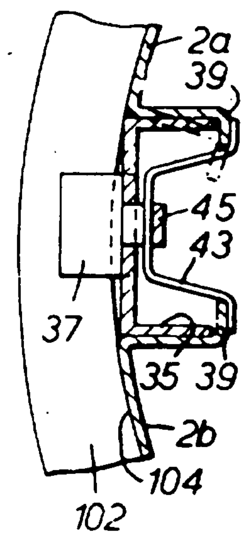

FIG.5.

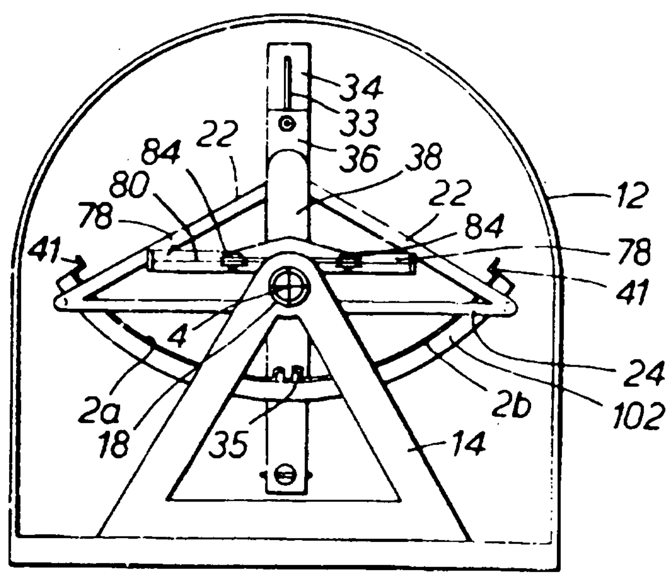

FIG.7.

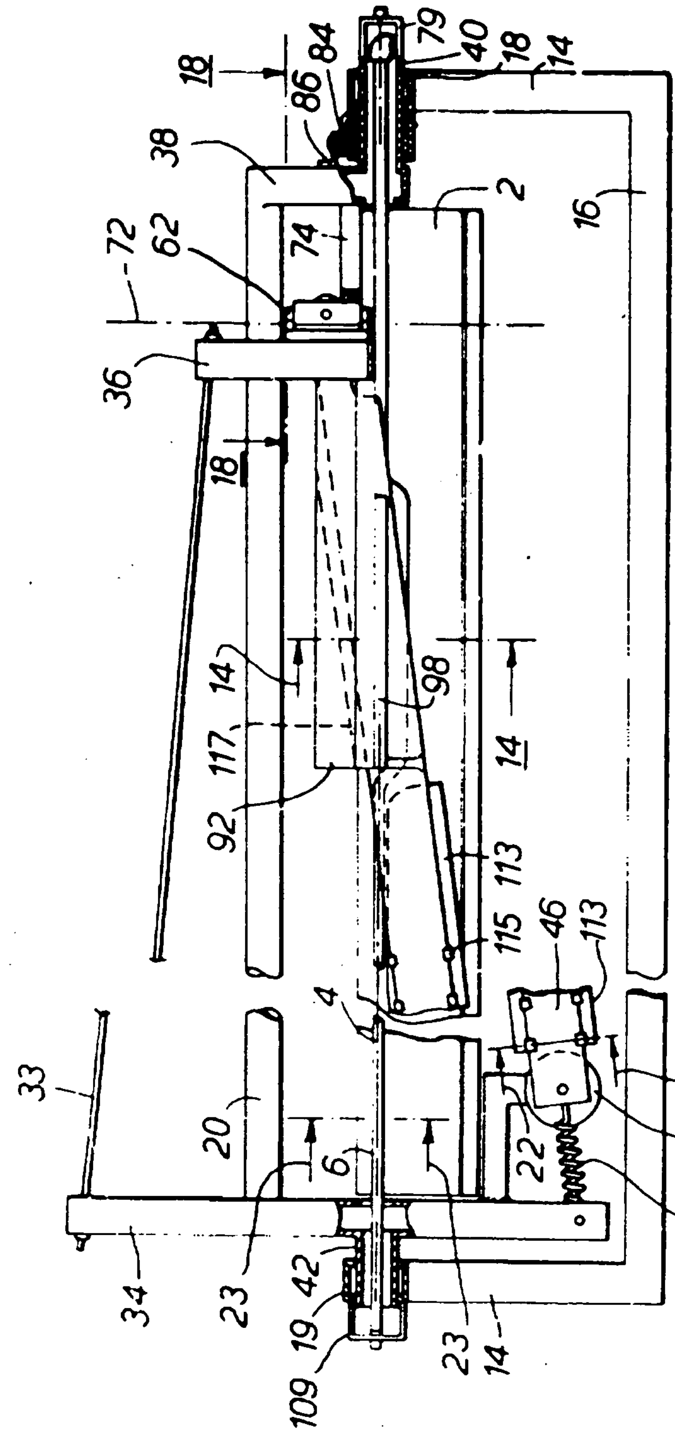

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FIG.8.

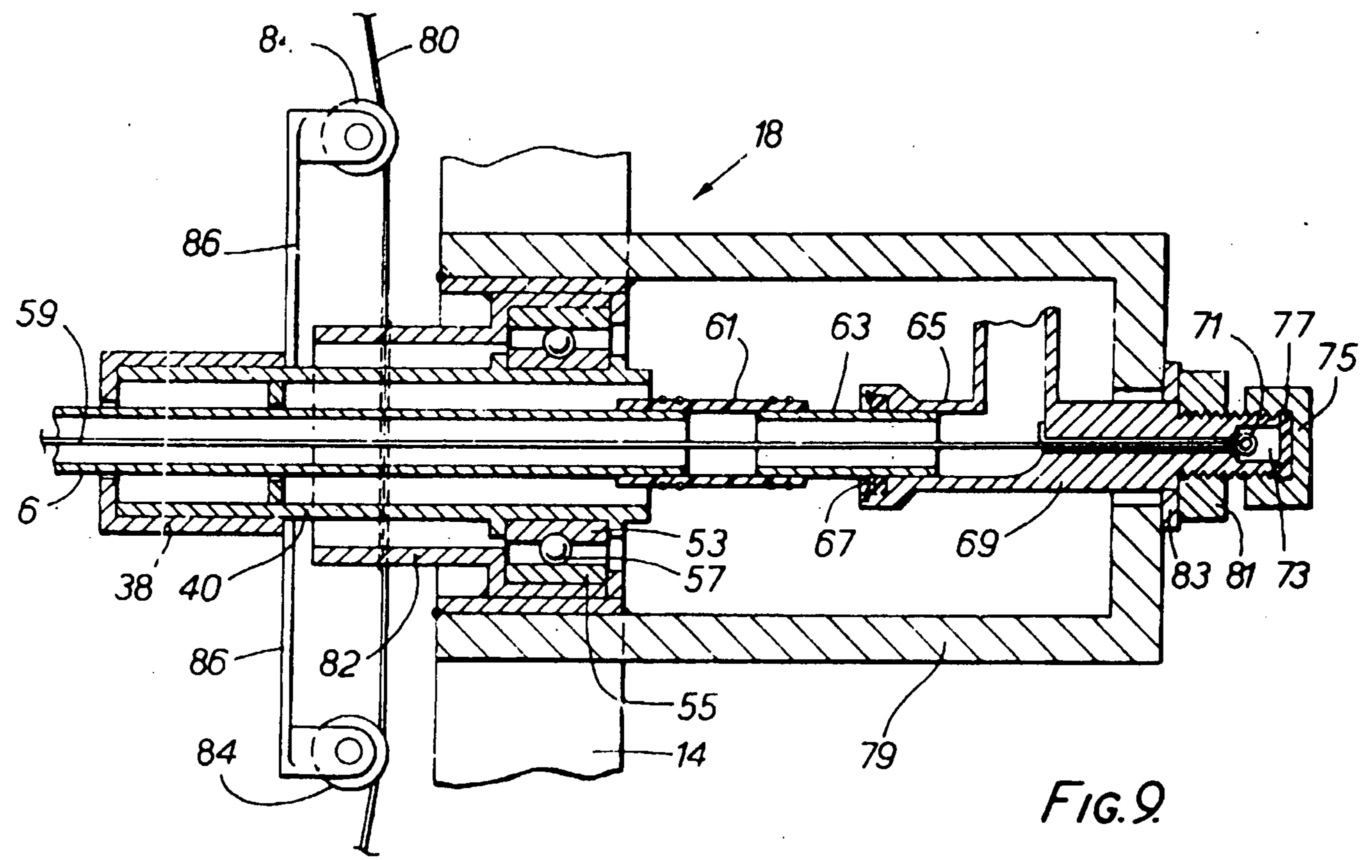

FIG.9.

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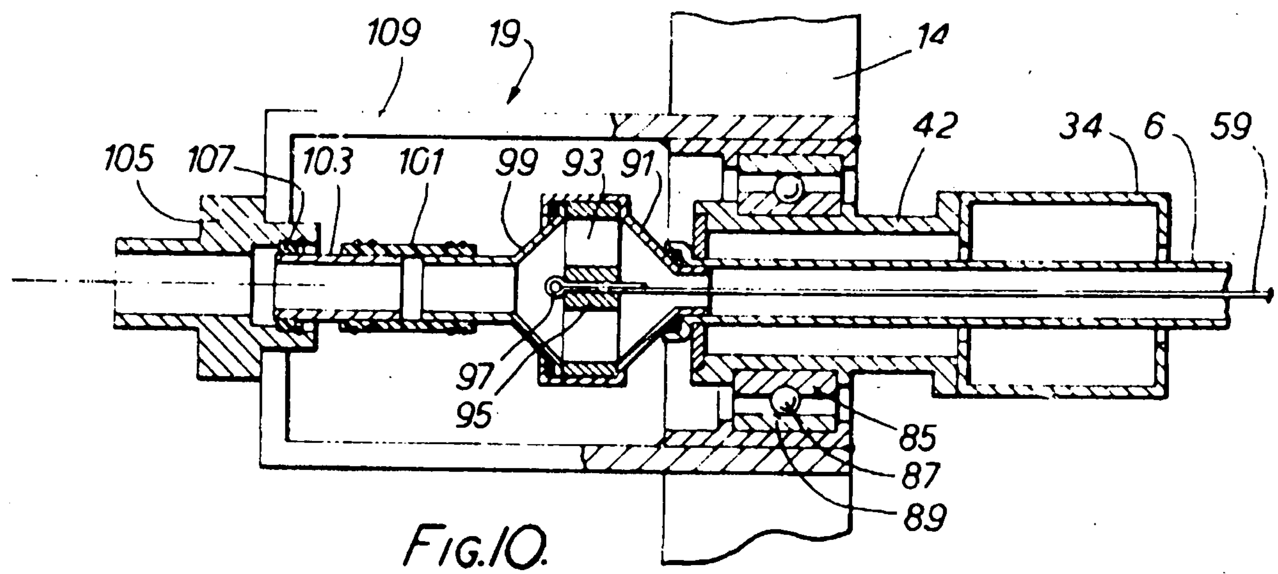

FIG.10.

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